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Reddy

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[54] **RPM INFORMATION SIGNAL GENERATING CIRCUITRY FOR ELECTRONIC FUEL CONTROL SYSTEM**

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[73] Assignee: **The Bendix Corporation,** Southfield, Mich.

[21] Appl. No.: **226,486**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 101,896, Dec. 28, 1970, Pat. No. 3,734,068.

[51] **Int. Cl.**[3] **H03K 5/04;** H03K 5/08; H03K 5/153

[52] **U.S. Cl.** **307/268;** 307/360; 307/265; 307/227; 307/228; 123/478;

[58] **Field of Search** 307/234, 235, 227, 228, 307/265, 268; 328/133–135; 123/102, 118

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,337,814	8/1967	Brase	328/134
3,386,037	5/1968	Yamada	328/134
3,391,344	7/1968	Goldberg	328/134
3,482,170	12/1969	Ananiades	307/235
3,521,174	7/1970	Naubereit	328/134
3,563,219	2/1971	Mieras	123/118
3,725,795	4/1973	Mesenhimer	328/135

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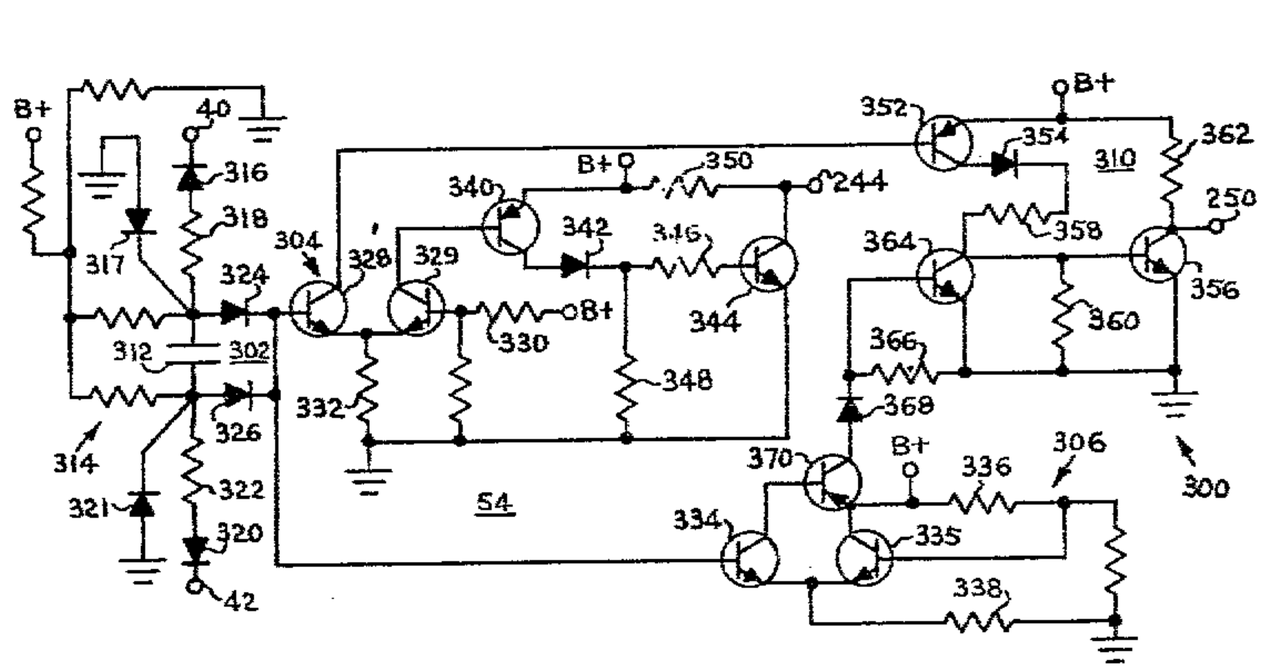
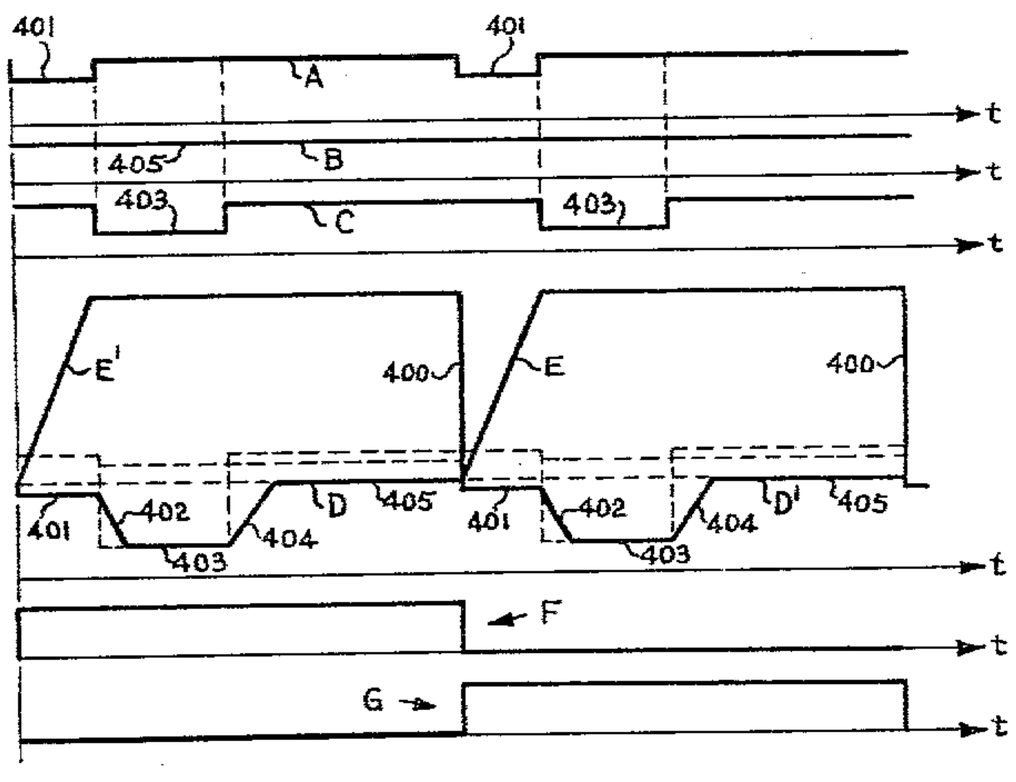
Attorney, Agent, or Firm—Gerald K. Flagg; Russel C. Wells

[57] **ABSTRACT**

A circuit for generating an rpm responsive information signal for electronic fuel control systems designed to provide intermittent actuation of a fuel delivery system is illustrated herein. In an electronic fuel control system which relies upon excursions of a controlled voltage through a selected threshold level to generate the injection controlling signal, a circuit is provided to control the variation, as a function of engine rpm, of the initial value of the injection controlling voltage. Means are also illustrated for updating the engine rpm information at least once per engine triggering event to provide improved fuel delivery response to variations in engine rpm.

5 Claims, 5 Drawing Figures





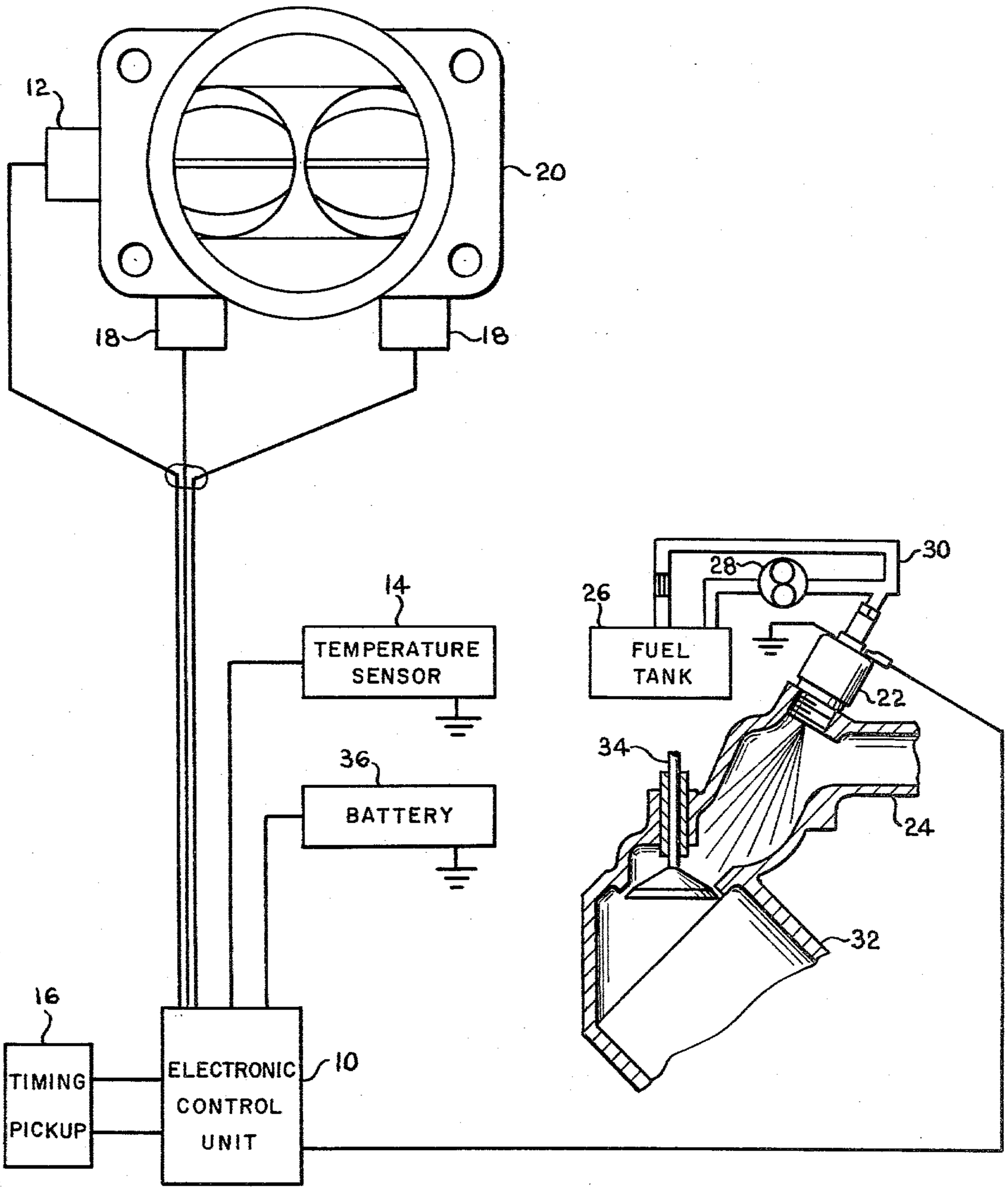

12
20
18
18
14
TEMPERATURE SENSOR
36
BATTERY
16
TIMING PICKUP
ELECTRONIC CONTROL UNIT
10
26
FUEL TANK
28
30
22
34
24
32

FIGURE 1

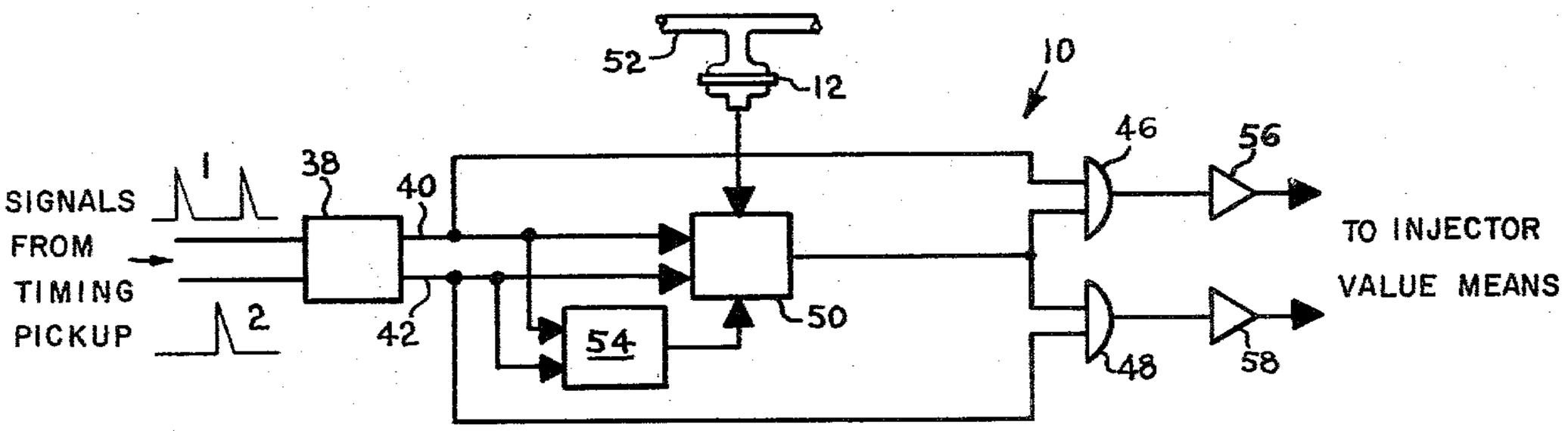


FIGURE 2

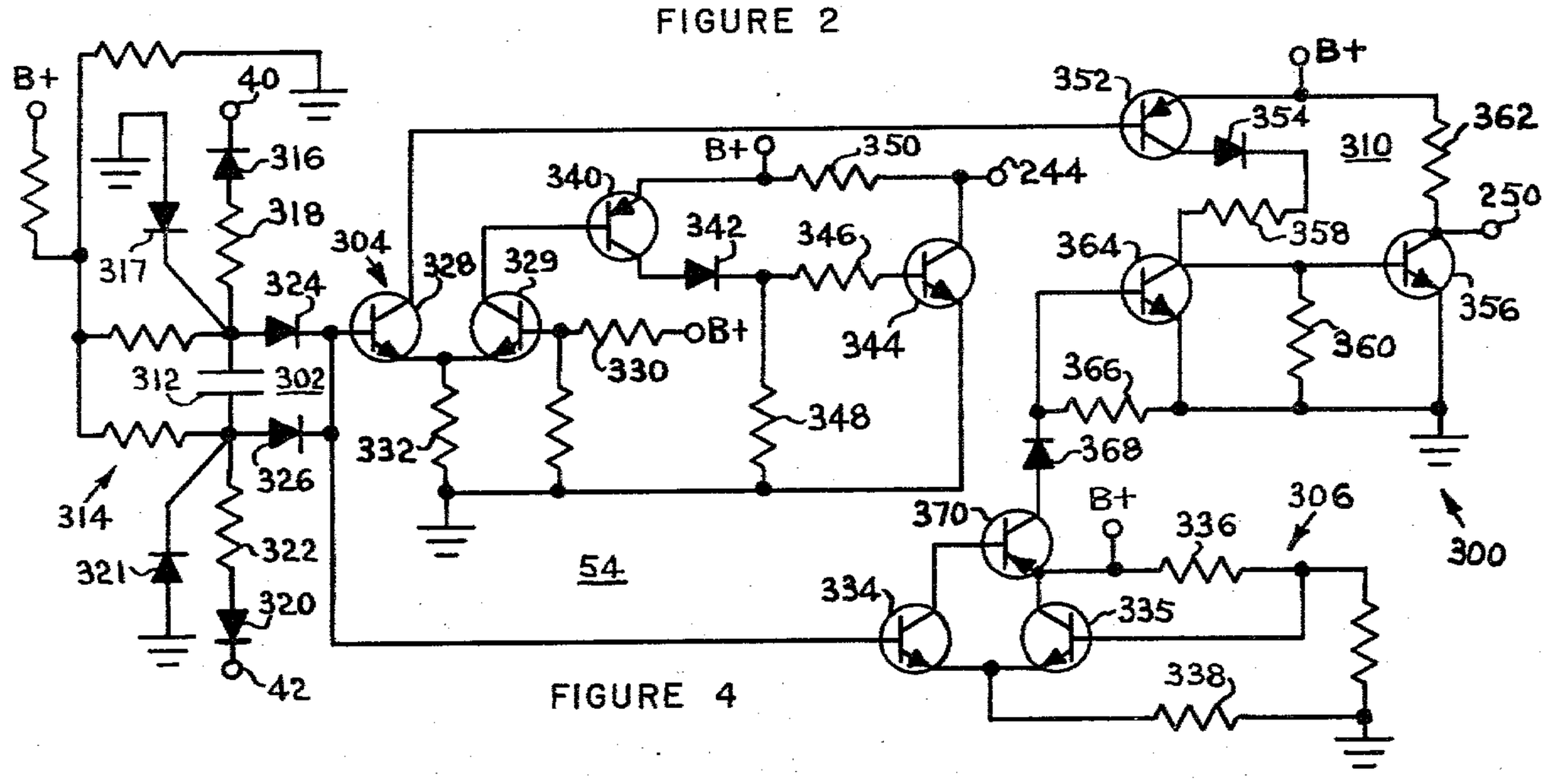


FIGURE 4

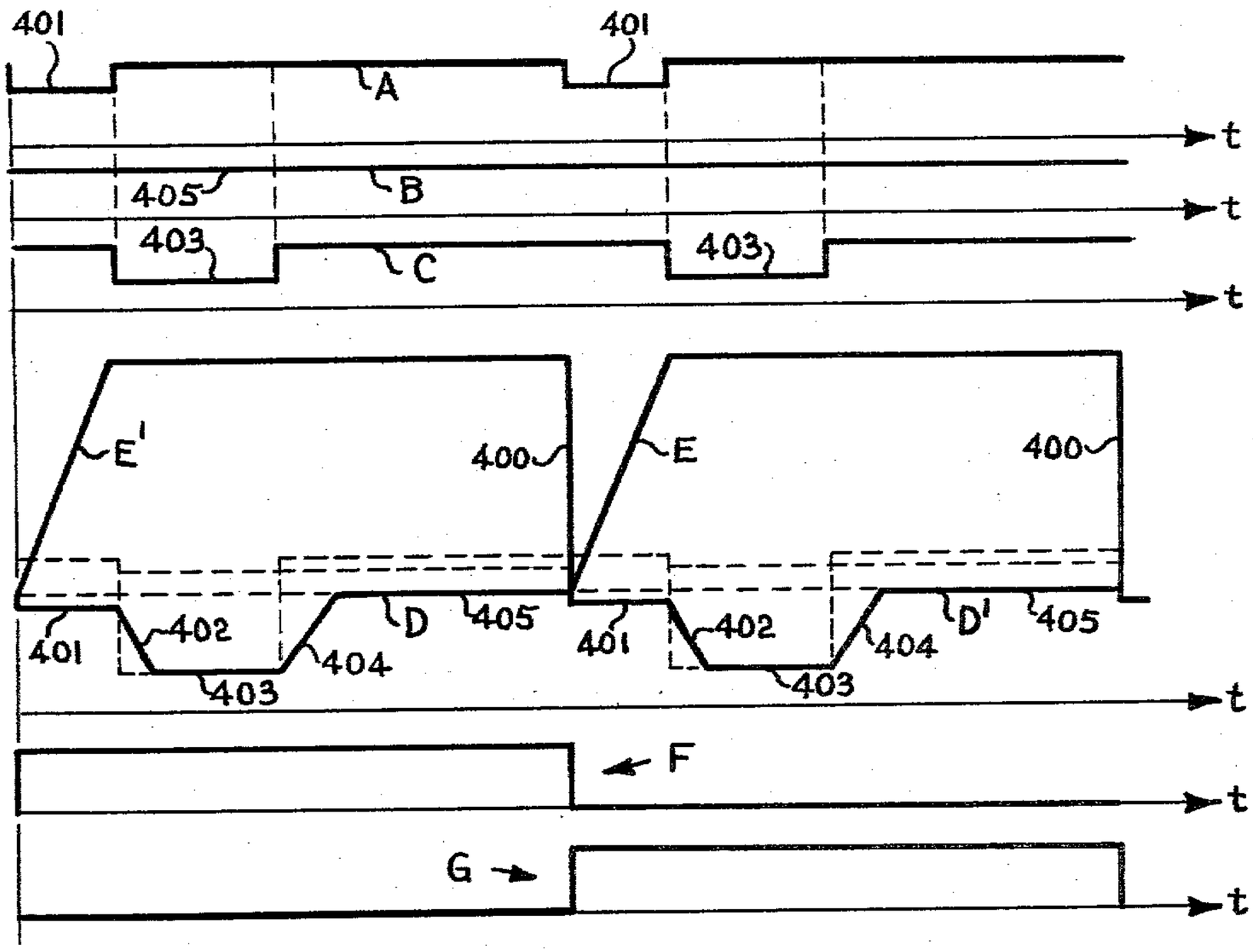
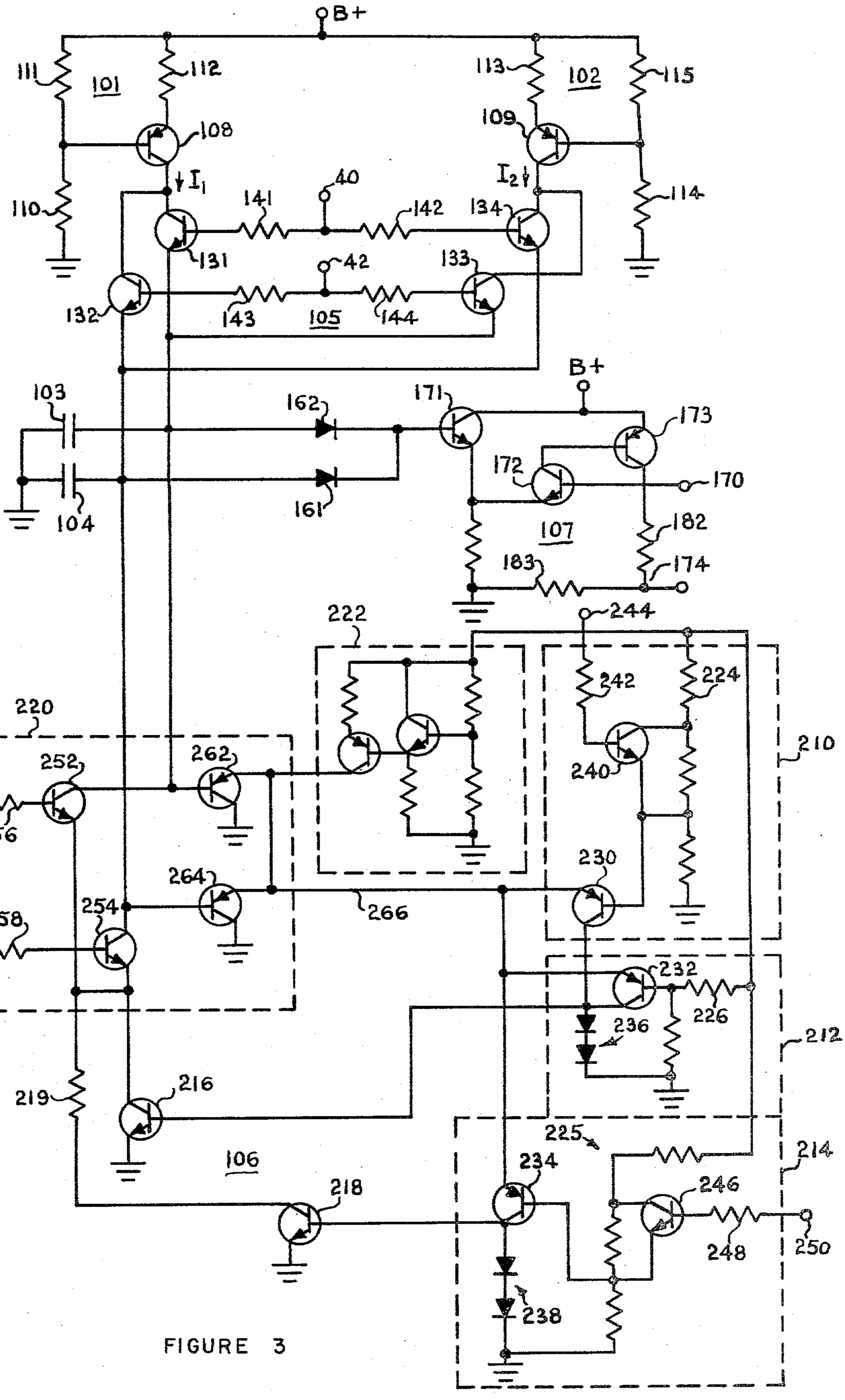


FIGURE 5


B+
111
101
112
113
102
115
108
109
I_1
I_2
40
110
141
142
134
114
131
42
133
132
143
105
144
B+
103
162
171
173
172
170
104
161
107
182
183
174
244
222
242
224
220
210
252
262
240
40
256
264
230
254
266
258
42
232
226
236
212
216
225
219
106
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214
218
246
248
250
238

FIGURE 3

RPM INFORMATION SIGNAL GENERATING CIRCUITRY FOR ELECTRONIC FUEL CONTROL SYSTEM

CROSS REFERENCE TO A RELATED APPLICATION

This application is a continuation-in-part of my co-pending patent application Ser. No. 101,896 "Fuel Injection Control System", filed Dec. 28, 1970 issued as U.S. Pat. No. 3,734,068 on May 22, 1973.

The present invention is related to my co-pending, commonly assigned patent application Ser. No. 226,498 entitled "Electronic Fuel Control System Including Electronic Means For Providing A Continuous Variable Correction Factor" filed Feb. 15, 1972.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is related to the field of electronic fuel control systems for providing intermittent pulses of fuel to a power producing engine. More particularly, the present invention is related to that portion of the above noted field in which the injection pulses are generated in a time period during which a controlled voltage maintains a selected relationship with respect to a selected threshold value and in which the varying engine operating conditions are used to alter the state of the voltage being examined and/or the level of the selected threshold value. More particularly, the present invention is related to a system by which the value which the injection controlling examined portion of the controlled voltage may originate at is controllably varied as a function of substantially instantaneous engine rpm values.

2. Description of the Prior Art

It is well known in the prior art that the fuel requirement for an engine operating at constant load may vary as a function of the rpm value of the engine. In prior electronic fuel control systems, the rpm corrections have been generally provided by taking the average speed of the engine for a period of time preceding the instantaneous calculation in question and by altering the voltage used to excite one or more of the engine operating parameter sensors.

This approach has presented two difficulties. Firstly, by taking an average of the engine speed over a history of prior events, however brief, the response to changes in engine rpm is slow. Secondly, by applying a variation in the exciting voltage to one or more of the engine parameter sensors, an additional delay has been induced as a result of the inherent response delays in the sensor or sensors so excited. For instance, it has normally been the case to vary the excitation voltage for the intake manifold air pressure sensor. Such a sensor has an internal time delay due to the electrical and mechanical characteristics with which it is designed. Thusly, by the time the information of a change in engine speed is available to affect a change in the amount of fuel delivered to the engine, the engine may be operating under a speed condition which is inappropriate for the amount of fuel being provided by the fuel delivery system at that moment. It is thus an object of the present invention to provide a means for examining the engine rpm on a current, or substantially instantaneous, basis so as to provide the proper quantities of fuel to the engine for each cycle of its operation.

With the advent of fuel delivery computing techniques which rely principally on the excursion of a selected voltage through a selected threshold value it has been determined that an rpm correction may be provided by varying one of the two extreme values which the selected voltage may obtain. That is, for injection systems which provide fuel while a selected voltage is below a reference value, it is possible to vary the value at which that voltage may be initiated so as to controllably vary its total time below the threshold value. My co-pending commonly assigned patent application Ser. No. 219,275 filed January 20, 1972, hereby expressly incorporated herein by reference entitled "Circuit for Providing Electronic Full-Load Enrichment Fuel Compensation in an Electronic Fuel Control System" illustrates a system in which a controlled voltage waveshape is generated having a first shaped portion which generates a correction factor and a second shaped portion following immediately thereon to generate the fuel controlling pulse. The correction factor is provided by controllably varying the initial or starting value of the second shaped portion which in turn varies the time required for the second shaped portion to reach a threshold value. This correction factor is used to provide rpm correction. However, the circuitry of my prior case is capable of providing rpm correction factors on a basis of whether or not engine speed is above or below one selected rpm value. It is now known that rpm correction factors are required as a function of existing speed conditions and the determination of only one rpm value is insufficient. With the circuitry of my prior case, provision of greater detailed rpm information is difficult.

This difficulty arises from the inability of the computing techniques normally used in electronic fuel control systems to identify any particular engine rpm value by means other than integration techniques. Integration techniques provide at best an identification of an engine rpm one cycle after that rpm value is desired and at worst an averaging technique which is the average of rpm values over several past cycles of rpm. For the greatest accuracy of fuel delivery, it is necessary that the rpm information be as current as possible. It is therefore an object of the present invention to provide a means of generating rpm information and for updating this information each injection time period.

In order to match the manufacturing, cost, and accuracy benefits derived from a fuel control system as described in my above-noted co-pending application it is a further object of the present invention to provide circuitry capable of generating rpm information which is completely compatible with the electronics of my prior co-pending application.

In view of the fact that the speed of electronic devices and electronic computing techniques greatly exceeds the speed of operation of an internal combustion engine, it is well within the state-of-the-art to examine the time interval between successive triggering events and to compute therefrom the speed of the engine to generate rpm information which is sufficiently current to meet the general accuracy levels obtained by the present invention. However, by waiting until the occurrence of the next succeeding engine event to generate speed information would require a system of additional electronics to compute the rpm information and to apply that factor to the injection command signaling portion of the system for instance as illustrated and claimed in my above-mentioned co-pending applica-

tion. It is therefore a still further object of the present invention to generate rpm information during the interval between successive triggering events which is available prior to the occurrence of the succeeding triggering event. As used herein "triggering event" is intended to mean the signal which is used to synchronize the fuel control system to selected angles of engine crank shaft rotation and also the condition of engine operation which gives rise to the signal.

I have determined that computation or generation of exact speed information per se is not necessary in order to achieve the objectives of the present invention and, in fact, the present invention provides suitable information in a form which is much more compatible with my aforementioned application and which is much less expensive to implement in circuit form than would be the electronics necessary to generate information of precise engine rpm. It is therefore an object of the present invention to provide circuitry for generating an rpm information signal which signal is being generated in the interval between successive triggering events without direct input of past triggering events and which does not rely upon the next succeeding triggering event for computation.

SUMMARY OF THE PRESENT INVENTION

The present invention provides electronic circuitry which is actuated by the occurrence of the triggering event and which thereafter generates an rpm signal as a function of the time elapsed from that triggering event. This signal may be used to control the variation in initial value of the computing waveshape. Due to the fact that the frequency of triggering events is proportional to the engine speed and therefore the duration of the interevent interval is inversely proportional to the engine speed, my invention continuously generates rpm information as a function of the time elapsed from the most recently to have occurred triggering event. Thus, information concerning the approximate engine speed will be present at the occurrence of the next succeeding triggering event but without the necessity of directly or indirectly computing the instantaneous engine speed. The present invention is characterized by providing a circuit means which responds to the occurrence of a triggering event and which provides as output as least one signal which occurs at a point in time after the triggering event and which time delay is predetermined to coincide with engine operation at or below a preselected rpm value. In a presently preferred embodiment of the present invention, a plurality of such signals are generated to indicate successively lower speeds of engine operation thereby defining regions of engine speed which may be adjusted to coincide with rpm values or points where the correction factor varies.

DESCRIPTION OF THE DRAWING

FIG. **1** shows, in diagramatic form, an electronic fuel control system for an internal combustion engine with which the present invention is of utility.

FIG. **2** shows a block diagram of one form of electronic control unit for use in the system of FIG. **1**.

FIG. **3** shows an electronic circuit realization of a portion of the electronic control unit of FIG. **2**.

FIG. **4** shows an electronic circuit realization of the present invention according to FIG. **2** and for utilization with the circuit of FIG. **3**.

FIG. **5** illustrates a series of voltage wave forms which illustrate the operation of the FIGS. **3** and **4** circuit diagrams.

DETAILED DESCRIPTION OF THE DRAWING

Referring now to FIG. **1**, an electronic fuel control system is shown in diagramatic form. The system is comprised of a main computing means or electronic control unit **10**, a manifold pressure sensor **12**, a temperature sensor **14**, an input timing means **16** and various other sensors denoted as **18**. The manifold pressure sensor **12** and the associated other sensors **18** are illustrated mounted on throttle body **20** but it will be understood that other mounting locations are possible. The output of the computing means **10** is coupled to an electromagnetic injector valve member **22** mounted in intake manifold **24** and arranged to provide fuel from tank **26** via pumping means **28** and suitable fuel conduits **30** for delivery to a combustion chamber **32** of but one of several forms of an internal combustion engine, otherwise not shown. While the injector valve member **22** is illustrated as delivering a spray of fuel toward an open intake valve **34**, it will be understood that this representation is merely illustrative and that other delivery arrangements are known and utilized. Furthermore, it is well known in the art of electronic fuel control systems that computing means **10** may control an injector valve means comprised of one or more injector valve members arranged to be actuated singly or in groups of varying numbers in a sequential fashion as well as simultaneously. The computing means is shown as energized by battery **36** which could be a vehicle battery and/or battery charging system as well as a separate battery.

The block diagram shown in FIG. **2** illustrates the computing means **10** in a nonparticularized manner as applied to two-group injection. In FIG. **2**, there is shown a switching device **38** capable of producing alternating output signals and receiving as input a signal or signals representative of engine crank angle as from sensor **16**. Mechanically, sensor **16** could be a single-lobed cam, driven by the engine and alternately opening and closing a pair of contacts. Since this arrangement could generate spurious signals, as by contact bounce, the switching device **38** will be described and discussed as a flip-flop since the flip-flop is known to produce a substantially constant level of output at one output location and zero level at the other output location in response to a triggering signal which need only be a spike input as illustrated by traces **1** and **2** but may also be of longer duration and a flip-flop may be readily made insensitive to other types of signals. Signals received on the nontriggering input will, of course, have no effect on a flip-flop. Output conductors **40** and **42** are connected to the input of unit **50**. Output conductors **40** and **42** are also connected to the inputs of a pair of AND gates with output conductor **40** being connected to one input of AND gate **46** and the output conductor **42** being connected to one input of AND gate **48**. Unit **50** receives, as primary control input, signals from the pressure sensor **12** indicative of an engine operating condition and, therefore, of the engine fuel requirement. Sensor **12** is here shown coupled to a manifold lead or runner **52**. The actual location of sensor **12** will depend upon the dynamic characteristics of the intake manifold and throttle body. Unit **50** also receives a signal from the rpm information signalling means **54** which is arranged to also receive the triggering signals from output

conductors **40, 42**. The output of the unit **50** is connected to a second input of each AND gate **46** and **48**. The output of AND gate **46** is connected to amplifier **56** which, in turn, supplies controlling current to the first injector group. AND gate **48** is connected to amplifier **58** which supplies controlling current to the second injector group. For the sake of simplification, the additional control inputs have been omitted.

As will be readily apparent, the presence of an output signal from the flip-flop **38** will occur at one output location to the exclusion of the other. This signal will then appear at one input of only one AND gate of only one amplifier. This signal selectively designates an injector or injector group for imminent injection. For the sake of example, it may be assumed that the output signal of the flip-flop **38** is at output location **40** so that the signal also appears at one input of AND gate **46**. The signal from the output **40** of the flip-flop **38** also appears at the unit **50** as well as the rpm information signalling means **54**. Unit **50** is operative to produce an output during the passage of a predeterminable amount of time. This time is determined by the values of the sensory input applied to unit **50** as well as by the input provided by the rpm information signalling means **54**. During this initial period of time the output of the unit **50** is providing a full-strength output signal. This signal is applied to one input of each of the AND gates **46** and **48**. Because of the intrinsic nature of AND gates, an output signal is produced only while an input signal is being applied to each and every input. This then dictates that AND gate **46** will produce an output to be amplified by amplifier **56** to open the first injector group since it is receiving an injector selection command directly from the flip-flop **38** and an injector control command from the unit **50**. At the end of the time delay period, unit **50** produces a zero level signal so that the injection control command output signal is removed from the input to the AND gate **46** and the output of the AND gate **46** goes to zero, thereby allowing the first injector group to close. During the period of time the first injector group is open, a metered amount of fuel under pressure is injected by the first injector group. Depending upon particular electronics selected, suitable amplifiers and/or inverters may be used to match obtainable signals with desired or necessary circuit responses.

Referring now to FIG. **3**, an electronic circuit is illustrated to satisfy the functional requirements of block **50** in the block diagram of FIG. **2**. The unit **50** is comprised of a pair of current sources **101, 102** which are alternately applied to a pair of timing capacitors **103, 104** by a switching network **105** receiving the triggering signals **40, 42**. Also receiving triggering signals **40, 42**, network **106** controls the level of the voltage on the selected capacitor **103, 104** prior to generation of the injection command signal. Threshold establishing circuit means **107** samples the highest voltage appearing across capacitors **103, 104** and compares this value with the level established by the signal received from pressure sensor means **12** at input port **170** to compute the fuel injection command signal.

The current source **101** is comprised of transistor **108** whose base is connected to the junction of a pair of voltage dividing resistors **110, 111** and whose emitter is connected to resistor **112**. The resistors **111** and **112** are connected to a source of potential identified as B+ and resistor **110** goes to ground. Current source **102** is similarly comprised of a transistor **109** whose base is coupled to the junction of voltage divider resistors **114, 115** and whose emitter is connected to resistor **113** which is also connected to the B+ source. This arrangement is operative to establish a known level of current flow in the collectors of transistors **108, 109**, respectively. The collector of transistor **108** is then connected in a parallel fashion to the collectors of a pair of transistors **131, 132**. Similarly, the collector of transistor **109** is connected in parallel to the collectors of a pair of transistors **133, 134**. The bases of transistors **131** and **134** are connected together through resistances **141, 142** while the bases of transistors **132, 133** are connected by way of resistances **143, 144**. The junction of resistances **141, 142** is arranged to receive the trigger signals from output **40** while the junction of resistances **143, 144** is arranged to receive the trigger signals from output **42**. The emitters of transistors **131** and **133** are connected to capacitor **103** while the emitters of transistors **132** and **134** are connected to capacitor **104**. This circuit is then arranged to provide the current flow from current source **101** through transistor **131** to capacitor **103** and the current from source **102** through transistor **134** to capacitor **104** whenever a high voltage signal appears on output **40** and a low voltage signal appears on output **42**. Whenever a low voltage signal is present on output **40** and a high voltage signal is present on output **42**, the current from source **101** will flow through transistor **132** to capacitor **104**, while the current from source **602** flows through transistor **133** to capacitor **103**.

The threshold establishing circuit receives a signal indicative of the manifold pressure at **170** and this signal is applied to the base of transistor **172**. The base of transistor **171** receives by way of diodes **161, 162** the signal from the one of capacitors **103, 104** whose accumulated charge, or voltage, is highest. As the emitters of transistors **171, 172** are coupled together, one of these transistors will be in conduction depending upon which has a base residing at a higher voltage value. When the value appearing on the base of transistor **171** exceeds the value appearing on circuit input **170**, transistor **171** will go into conduction and transistor **172** will drop out of conduction. Termination of conduction of transistor **172** will consequently terminate conduction of transistor **173**. While transistor **172** was conducting, transistor **173** was also conducting and a relatively high voltage signal was present at circuit location **174** due to the voltage divider action of resistors **182, 183**. However, termination of conduction of transistor **173** will result in a substantially zero or ground level signal appearing at circuit location **174** due to the lack of current flow through the resistors **182, 183**. This output signal may be applied to the AND gates **46, 48** in the FIG. **2** embodiment to constitute an injection command signal.

The timing capacitor discharging and initial charge controlling circuitry **106** is comprised of a plurality of reference level establishing means **210, 212**, and **214**, a pair of discharging means **216, 218**, switching means **220** and a current source means **222**. The reference level establishing means **210, 212**, and **214** are connected to the source of energy indicated as B+ and are comprised of voltage divider means **224, 226**, and **228**, respectively, and voltage signal communicating transistor means **230, 232**, and **234** respectively. The voltage communicating transistor means **230, 232**, and **234** are arranged to have their bases communicated to a portion of the voltage divider means so that a known level of voltage may appear thereon and their emitters are connected to a common point. The collectors of the transis-

tors **230** and **232** are coupled together and are communicated to ground through a diode means **236** while the collector of transistor **234** is communicated to ground through a separate diode means **238**. The collector/diode junction of the transistors **230, 232** and diode means **236** is communicated to the discharging means **216** while the collector/diode junction of transistor **234** and diode means **238** is communicated to the discharging means **218**.

Reference level establishing means **210** further includes a transistor **240** whose collector and emitter terminals are arranged to short circuit at least a portion of the voltage divider means **224** when the transistor is in conduction. The base of transistor **240** is coupled to resistance **242** which is in turn coupled to external terminal **244**. Similarly, reference level establishing means **214** includes a transistor **246** arranged in short circuit relationship to at least a portion of the voltage divider means **228**. Resistance **248** appears in the base circuit **246** and this is communicated to external terminal **250**.

Energy dissipating means **216** and **218** are here illustrated as transistor elements having their emitter electrodes connected to ground and their base electrodes connected to the collectors, respectively, of transistor members **232** and **234**. The collector of transistor **216** is coupled to switching means **220** while the collector of transistor **218** is coupled to resistance **219** which is in turn coupled to switching means **220**.

The switching means **220** is comprised of a pair of transistors **252, 254** having resistors **256** and **258** in their base circuits. Resistor **256** is further connected to terminal **40** and resistor **258** is connected to terminal **42**. The emitters of the transistors **252** and **254** are coupled together through circuit connection **260** and this common circuit connection is in turn connected to the energy dissipating means **216** and **218**. In the illustrated embodiment this is accomplished by connecting the collector of transistor **216** to the common junction and the collector of transistor **218** through further resistor **219** which is then connected to the common junction **260**. The collector of each of the switching transistors **252, 254** is coupled to the base of a regulating transistor **262, 264** respectively and each of these collector-base connections is connected to one of the two timing capacitors **103, 104** so that switching transistor **252** is coupled to regulating transistor **262** and also to timing capacitor **103** while switching transistor **254** is coupled to regulating transistor **264** and also to timing capacitor **104**.

The regulating transistors **262, 264** and the controlled regulation transistors **230, 232** and **234** are intercoupled in a common-emitter configuration by common circuit location **266** coupled directly to each of the emitters of the five above enumerated transistors. Each of the five transistors is illustrated as being a pnp transistor with the regulating transistors **262, 264** having their collectors connected to ground and the controlled regulation transistors **230, 232** and **234** having their collectors connected to ground through a diode means which is here illustrated as the pairs of diodes identified as **236** and **238**.

Current source means **222**, which is herein illustrated as a conventional transistorized current source, is operative to provide a known level of current to the common circuit location **272**. As is known in the art, the configuration comprising the transistors **230, 232, 234, 262**, and **264** each having a voltage signal applied to the base thereof will have only those transistors in conduction which have the lowest identical base voltage. In the event that there is a single base residing at a lowest potential, that transistor and only that transistor will be in conduction and all others will be turned off due to the fact that the common emitters will be residing at a potential which is one pn junction above the value of the lowest base voltage and this value will be insufficient to forward bias any other emitter-base junctions.

The circuit as illustrated is arranged to provide the lowest voltage potential at the base of controlled regulation transistor **232** when signals are present on each of the input terminals **244, 250**. In such a configuration, and assuming a varying voltage appearing across both the timing capacitors **103, 104**, whenever the potential appearing across the appropriate one of the timing capacitors becomes identical with the voltage appearing on the base of the controlled regulation transistor **232**, the regulating transistor which is coupled to the appropriate timing capacitor will begin to conduct so as to maintain that timing capacitor at the potential then appearing on the base of transistor **232**. By suitably arranging the various resistive values within the voltage divider resistive networks **224, 226** and **228**, it can be arranged that the base of the controlled regulation transistor **232** will be at a value lower than the base of either of controlled regulation transistors **230, 234** while the shorting transistors **240** and **246** are switched on and will be at a higher value than at least one of the bases of controlled regulation transistors **230, 234** while either of shorting transistors **240** and **246** is not conducting. Furthermore, it can be arranged that the lowest voltage appearing at any of the three bases **230, 232, 234** may be sequentially varied by controlling the conductive states of the shorting transistors through the signals applied to the external terminals **244, 250**.

Referring now to FIG. **4**, a circuit according to the present invention is illustrated for generating rpm information in a presently preferred embodiment to selectively control the voltage appearing at the external terminals **244, 250** of the circuit **300** of FIG. **3**. The circuit is comprised of a triggering section **302**, a plurality of switching sections **304, 306** and a plurality of signal generating means **308, 310**. The triggering section is centered about **312** and further comprises resistive means **314** providing a voltage divider between the source of energy B+ and the ground as indicated for each terminal of capacitor **312**. Input signalling leads comprising a diode and resistor also intercommunicate each terminal of capacitor **312** with the triggering output conductors **40** and **42**. For example, diode **316** and resistance **318** intercommunicate the output conductor **40** with one side of capacitor **312** while diode **320** and resistance **322** intercommunicate the other side of capacitor **312** with the output conductor **42**. Each side of capacitor **312** is also communicated to the bases of two transistors in the switching sections **304, 306** by further diodes **324, 326**.

The switching section **304** is comprised of an emitter coupled pair of transistors **328, 329**, and a reference voltage divider means **330**. The emitter coupled pair of transistors are comprised of a pair of npn transistors having their emitters coupled to a further resistance **332** going to ground and having the collector of transistor **329** coupled to signal generating means **308** and the collector of transistor **328** coupled to signal generating means **310**. The switching section **306** is similarly comprised of an emitter coupled pair of transistors **334, 335** and a reference voltage divider means **336**. The emitter coupled pair of transistors have their emitters coupled

to a further resistance **338** going to ground while the collector of transistors **335** is coupled to the B+ source of energy and the collector of the transistor **334** is coupled to the signal generating means **310**.

Signal generating means **308** is comprised of transistor **340** whose base is coupled to the collector of transistor **329** and whose emitter is connected to the B+ source of energy. The collector of transistor **340** is coupled to anode of diode **342** whose cathode communicates with the base of transistor **344** through resistance **346**. The cathode of diode **342** is also coupled to ground through resistance **348**. The collector of transistor **344** is connected to the source of B+ supply through resistance **350** and the junction formed by resistance **350** and the collector of transistor **344** is then communicated to terminal **244** so that, in the presence of a current flow through transistor **344** the signal present on terminal **244** will be substantially the ground or low level signal and in the absence of current flow through transistor **344** the terminal **244** will be at a relatively high voltage value near the B+ supply.

Similarly, signal generating means **310** is comprised of an input transistor **352** whose emitter is connected to the B+ source of supply and whose base is communicated to the collector of transistor **328**. The collector of transistor **352** is connected to the anode of diode **354** while the cathode of diode **354** is coupled to the base of output transistor **356** through resistance **358**. The cathode of the diode **354** is also coupled to ground through resistance **360**. The collector of transistor **356** is coupled to the B+ source of supply through resistance **362** and the junction formed between the collector of transistor **356** and the resistance **362** is communicated to the terminal **250**. Signal generating means **310** also includes a further transistor **364** which is arranged to short circuit the resistance **360**. The base of transistor **364** is coupled to resistance **366** and the cathode of diode **368** while the emitter of transistor **364** is connected to ground as is the other side of resistance **366**. The anode of diode **368** is connected to the collector of transistor **370** whose base is coupled to the collector of transistor **334** within the switching section **306** and whose emitter is connected to the B+ source of supply.

Referring now to FIGS. **3**, **4** and **5** the operation of the present invention will be illustrated. Receipt of a triggering signal on the appropriate input lead will result in the signals on output conductors **40** and **42** to be substantially as illustrated in FIG. **5**. That is to say a relatively high signal will appear on conductor **40** and a ground or zero level signal will appear on conductor **42**. The zero level signal received on lead **42**, when applied to the appropriate terminals of the circuit of FIG. **3**, will be operative to turn off the various transistors which are in communication through their control electrode with the conductor **42** (for example transistors **132**, **133**, and **254**). The presence of the high voltage signal on lead **40** will be operative to turn on those transistors whose control electrodes are in communication with the lead **40** (for example transistors **131**, **134** and **252**). Thusly, the current identified as I_1 will be applied to the timing capacitor **103** while the current identified as I_2 will be communicated to the timing capacitor **104**. Also, the timing capacitor **103** will be communicated by way of transistor **252** to the common circuit connection **260**. The preceding cycle of operation of this system will have provided the timing capacitor **103** with a relatively high voltage at the instant of switching. This voltage is communicated to the base of transistor **262** while the voltage then appearing on timing capacitor **104** which is some lower value is communicated to the base of transistor **264**. Immediately following a triggering event, a current will be flowing through the diode means **236** from the reference level establishing means **210** as described hereinbelow. The presence of this current flow will be operative to turn energy dissipating transistor **216** on. This transistor, being turned on and communicated to the common circuit point **260**, will be operative to dump the voltage then appearing on timing capacitor **103** and the voltage on the base of transistor **262** will drop. As this voltage approaches the voltage appearing on the base of the one transistor of the pair of transistors **230** which is providing the current flow through the diode means **236**, this transistor will begin to turn off and the transistor **262** will begin to turn on due to their common emitter configuration. This switching off of the transistor **230** will result in the switching off of the transistor **216** and the voltage appearing on the timing capacitor **103** will then be regulated to the lowest voltage then appearing on the bases of transistors **230**, **232**, and **234**. Since this initial phase of regulation will occur within the nominal switching time of electronic devices (which is known to be quite short) the voltage on the capacitor **103** will be regulated to the value of the portion **401** of the curve D of FIG. **5**. Continued current flow of I_1 in the direction of timing capacitor **103** will flow to ground through the transistors **252** and **216**.

The presence of a high voltage signal on lead **40** will have no effect upon the circuit of FIG. **4** since it will be blocked from transmittal to capacitor **312** by the diode member **316**. However, the presence of a low voltage signal on input lead **42** will have the effect of drawing the side of capacitor **312** which is coupled to lead **42** to a very low near ground potential. The other side of capacitor **312** which was near ground during the preceding phase of operation will be held near ground by diode **317**. The transistors **329** and **335** will go into conduction due to the presence of the relatively high voltage signals appearing on their bases. The conduction of transistor **329** will be operative to cause transistor **340** to conduct providing a base current flow to transistor **344** through diode **342** to resistance **346** causing transistor **344** to go into conduction. This will generate a relatively low, near ground, level signal on terminal **244** causing transistor **240** (FIG. **3**) in the reference level establishing means **210** to be nonconductive. This will cause the voltage divider means **224** to establish a low level voltage signal on the base of transistor **230** which, by suitable arrangement of the resistive elements within the voltage divider networks **224**, **226**, **228** can be arranged to cause the base of transistor **230** to be at a potential lower than that of the bases of transistors **232** and **234**.

While transistors **328** and **334** (FIG. **4**) are nonconductive, the transistors whose bases are coupled to the collectors of the nonconductive transistors **328** and **334** (transistors **352** and **370**) will also be nonconductive. This will cause transistor **356** to be nonconductive and the voltage appearing on terminal **250** will be a relatively high voltage. This relatively high voltage applied through resistance **248** (FIG. **3**) to the base of transistor **246** will be operative to cause transistor **246** to be conductive thereby shortcircuiting a portion of the voltage divider means **228** and applying a relatively high level of voltage signal to the base of transistor **234**.

As the charge appearing across capacitor **312** (FIG. **4**) begins to increase, the voltage applied to the bases of the nonconductive transistors **328, 334** will begin in increase. When this voltage reaches the switching levels established by the voltage divider means **330** and **336**, the conductive state of the transistors within the two emitter coupled pairs will reverse. By suitably arranging the voltage dividers **330** and **336**, the emitter coupled pair of transistors comprised of transistors **328** and **329** can be arranged to switch its conductive state earlier in time than the emitter coupled pair of transistors comprised of transistors **334** and **335**. This can be accomplished by making the base voltage on transistor **329** lower than the base voltage on transistor **335** so that the charge across capacitor **312** as it increases will reach the value on the base of transistor **329** prior to the point in time when it reaches the value on the base of transistor **335**. Upon switching of the current flow from transistor **329** to transistor **328**, the transistor **340** will drop out of conduction while the transistor **352** begins to conduct. This will have the effect of turning off transistor **344** and turning on transistor **356**. This will cause the voltage appearing on terminal **244** to increase and the voltage appearing on terminal **250** to decrease. This will establish the fact that engine rpm is less than the rpm associated with the time period required for capacitor **312** to charge to the value represented by the voltage divider **330**. The effect of this upon the reference level establishing means **210** and **214** (FIG. **3**) will be to switch on the transistor **240** and to switch off the transistor **246** so that the voltage appearing at the base of transistor **234** will decrease. Again by suitable arrangement of the various resistive values the voltage at the base of transistors **234** can be arranged to be lower than the voltage at the base of either of transistors **230, 232**.

Assuming that the actual engine rpm value is relatively low so that the period of time between successive triggering events is relatively long, the charge across capacitor **312** (FIG. **4**) will continue to increase until such time as it reaches a value established by the voltage divider **336** indicative of engine rpm lower than a second predetermined value. The current flow will then switch from transistor **335** to transistor **334** and transistor **370** will be switched on. This will provide a current flow through diode **368** to the transistor **364** within the signal generating means **310** providing a shortcircuit for current flow from transistor **352**. The effect of this shortcircuit will be to prevent base current from entering the base of transistor **356** thereby turning that transistor off and causing the voltage signal appearing at terminal **250** to increase from the low or near ground level signal to a relatively high signal thereby establishing the second rpm breakpoint. This increase of voltage at the terminal **250** of the reference level establishing means **214** (FIG. **3**) will be operative to trigger transistor **246** back into conduction thereby raising the voltage applied to the base of transistor **234**. This increase in voltage at the base of transistor **234** coupled with the previous increase in voltage applied to the base of transistor **230** can readily be arranged through suitable selection of the resistive values in the voltage divider network **226** to render the base of transistor **232** lowest among the three so that the voltage appearing across the appropriate timing capacitor will be regulated to that value.

With specific reference now to FIG. **5**, the curve identified as A represents the voltage applied to the base of transistor **230** as a function of time while the curve B represents the voltage applied to the base of transistor **232** as a function of time and the curve C represents the voltage applied to the base of transistor **234** as a function of time. The effect of the curves A, B, and C may be combined through the above described regulating action to produce the rpm correction waveform as shown in the graph representing the voltage applied to the timing capacitors. This voltage waveform is identified as D and represents the voltage applied to the timing capacitor **103** to provide desired rpm correction while the portion of the curve identified as E represents the voltage applied to the timing capacitor **103** (by current I_2) to generate the injection pulse. Waveforms D′ and E′ are also illustrated and represent the voltages appearing on the timing capacitor **104** during the same time period. The voltage waveforms F and G represent the triggering signals appearing on triggering conductors **40** and **42** respectively. It will be observed that the waveform D does not exactly coincide with the waveforms A, B, and C as waveform D contains ramp portions which occur at points in time coincident with the step functions.

The waveforms D and D′ are comprised of level portions identified as **401, 403, 405** and two sloped portions **402, 404**. In addition, the transition from waveform E′ to successive waveform D′ is indicated by portion **400**. The portion of the curve D identified as **401** is a voltage level corresponding to the lowest portion of the waveform A also identified as **401**, the portion identified as **403** corresponds to the lowest portion of the waveform identified as C, also identified as **403**, while the portion identified as **405** corresponds to the curve B. The sloped portion **402** represents the rate of decay of the accumulated charge on the timing capacitor through resistance **219** and transistor **218** and the slope of this portion is controlled by the value of resistance **219**. The sloped portion **404** is controlled by the rate of charging of the appropriate timing capacitor provided by the current I_1. The near vertical portion identified as **400** represents the drop in the voltage across the appropriate timing capacitor as the value decreases from that represented by the curve E through that represented by the initial portion of the curve D as the accumulated charge is "dumped" through transistor **216**. The curve E is generated by the current flow I_2 being applied through the appropriate switching transistors to the appropriate timing capacitor and is additive to the value of voltage across the appropriate timing capacitor at the point in time of switching.

I claim:

1. A circuit for providing a speed indicative signal to indicate the speed of operation of an associated device wherein the device includes means for generating a pulse train of triggering even pulses, each said pulse indicative of the occurrence of a periodically occurring event and comprising a pulse starting portion and a pulse ending portion defining therebetween a pulse duration varying only with the speed of said associated device, said circuit comprising in combination:

event responsive means responsive to one of said triggering event pulses operative to produce an event signal characteristic having a magnitude which starts at predetermined starting level in response to said pulse starting portion, varies from said predetermined starting level at a predetermined rate for a time varying only with the time elapsed from said pulse starting portion, and is reset to said starting level on the occurrence of a said

pulse ending portion, said event responsive means comprising first and second sources of constant potential, timing capacitor means comprising first and second terminals, first and second unidirectional current conducting devices each having first and second electrodes, said first electrodes being connected respectively to said first and second terminals, and circuit means operative in response to said first and second pulse portions to permit said first and second constant potential sources to alternately charge and discharge said capacitor respectively at said first and second terminals whereby said event signal characteristics are alternately provided and removed thereat;

reference establishing means operative to generate first and second signals representative of respective first and second of elapsed time from the occurrence of said pulse starting portion;

comparison means connected to said reference establishing means and commonly connected to said second electrodes of said unidirectional current conducting devices operative to generate first and second output signals each switchable from a first to a second value when said event signal characteristic exceeds said first and second representative signals respectively; and

utilization means connected to said comparison means operative during a said duration to generate a waveform having levels determined in accordance with said first and second values.

2. A circuit responsive to the variable duration defined between successive first and second pulse portions of a pulse train pulse and varying only with the speed of an associated device, said circuit providing at least two multi-level output signals and changing the level of one signal at a time when the other is not changed comprising:

first and second output signals providing means for respectively providing first and second output signals;

first switching means responsive to a control signal for controlling said first signal providing means and for changing the level of said first output signal when said control signal reaches a first predetermined value;

second switching means responsive to said control signal for controlling said second signal providing means and for changing the level of said second output signal when said control signal reaches a second predetermined value different from said first predetermined control signal value;

control signal providing and resetting means for providing said control signal having a value that varies at a predetermined rate from a predetermined starting level in response to the occurrence of a said first pulse portion and for resetting said control signal to said predetermined starting level in response to the occurrence of a said second pulse portion, said control signal providing means comprise means for responding to complementary first and second input signals, each having alternate high level and low level states defined by said first and second pulse portions, said control signal providing means including:

a capacitor;

first signal transmitting means for transmitting a first input signal to one side of said capacitor, the application of a low level signal to said first transmitting means discharging said one side of said capacitor, and the application of a high level to said first transmitting means permitting a charged build on one side of said capacitor;

second signal transmitting means for transmitting a second input signal to the other side of said capacitor, the application of a low level signal to said second signal transmitting means discharging said other side of said capacitor, and the application of a high level signal to said second signal transmitting means permitting the charging of said other side of said capacitor;

third signal transmitting means for transmitting voltage to both sides of said capacitor at a predetermined rate, the voltage on said capacitor comprising said control signal having a value that increases at a predetermined rate;

unidirectional current conducting means connecting each side of said capacitor with said first and second switching means to provide said conrol signal increasing at said predetermined rate to both said first and second switching means in response to a signal increase on either side of said capacitor; and

means connecting said first switching means with said second signal providing means for also changing the level of said second output signal when said control signal reaches said first predetermined value, the circuit thereby providing at least three output signal level changes in response to a variation of said control signal through said first and second predetermined values.

3. The signal providing circuit of claim 2 in which:

said first output signal providing means comprise means responsive to said first switching means for increasing the level of said output signal when said control signal reaches said first predetermined value; and

said second output signal providing means comprise means responsive to said first switching means for decreasing the value of said second output signal when said control signal reaches said first predetermined value, and means responsive to said second switching means for increasing the level of said second output signal when said control signal reaches said second predetermined value.

4. The signal providing circuit of claim 3 in which:

said second predetermined control signal value is greater than said first predetermined control signal value; and

said control signal providing means comprise:

means for providing a control signal having a value that increases at a predetermined rate; and

means for reducing the level of said control signals at regular intervals to thereby form a cyclic control signal having a frequency determining the level changes provided to said first and second output signals.

5. A circuit for generating and utilizing a variable number of predetermined elapsed time signals between successive pulses of a pulse train, said pulses comprising successive first and second pulse portions defining therebetween a duration varying only with the speed of an associated device, said circuit comprising:

(a) pulse train generating means responsively connected to said device for generating a pulse train comprising said pulses;

(b) control signal initiating-varying-and-resetting means for initiating a single control signal at a

predetermined starting level in response to said first pulse portion, varying said control signal at a predetermined rate between said predetermined starting level and a first predetermined elapsed time level when said duration is less than a first predetermined duration, between said first predetermined elapsed time level and a second predetermined elapsed time level when said duration is less than a second duration greater than said first duration, and above said second predetermined elapsed time level when said duration exceeds said second duration, and resetting said control signal to said starting level in response to said second pulse portion, said control signal initiating-varying-and resetting means comprising first and second sources of constant potential, timing capacitor means comprising first and second terminals, first and second unidirectional current conducting devices each having first and second electrodes, said first electrodes being connected respectively to said first and second terminals, and circuit means operative in response to said first and second pulse portions to permit said first and second constant potential sources to alternately charge and discharge said capacitor respectively at said first and second terminals whereby said control signals are alternately provided and removed thereat;

(c) reference level generating means for generating first and second predetermined reference levels indicative of said duration respectively at said first and second predetermined elapsed time levels;

(d) comparator and elapsed-time signal generating means connected to said second electrodes of said control signal generating means unidirectional current conducting devices and said reference level generating means for comparing said control signal and said first and second predetermined reference levels and generating a first of said variable number predetermined elapsed time signals only when said duration exceeds said first duration and a second of said variable number predetermined elapsed time signals only when said duration exceeds said second duration; and

(e) utilization means connected to said comparator means for generating a waveform during a said duration, said waveform having a first breakpoint determined in response to said first variable number predetermined elapsed time signal and a second breakpoint determined in response to said second variable number predetermined elapsed time signal.

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